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(72) & (74) continued overleaf

(54) Turbine blade making method and blade twisting devices

(57) The method comprises heating a blade blank, shaping it in a closed die in a superplastic state, machining the blank, then twisting and heat treating it.

The shaping is by extrusion into a blind cavity in a one-piece die.

The heating may be during or after twisting.

One blade twisting device (Fig. 7) comprises movable top part (43) and stationary bottom part (41) with elastic inserts in their surfaces gripping blank (35).

Blank (35) is pulled lengthwise by fixture (34) pulled by driving means (33) and twisted as it is pulled by a pin on rotatable disc (39) engaging in a slot (37) in guide (36).

A second blade twisting device (Fig. 5) comprises an assembly of rings (5 and 8–14) each having a pin (7) on one side and an abutment (6) on the other, the abutm nt being arranged to engage with the pin on the adjacent ring, and a blank (20) holding mechanism (19). Driving means (1) rotates ring (5) and subsequently the other rings. The rings are divided with changeable wooden inserts.

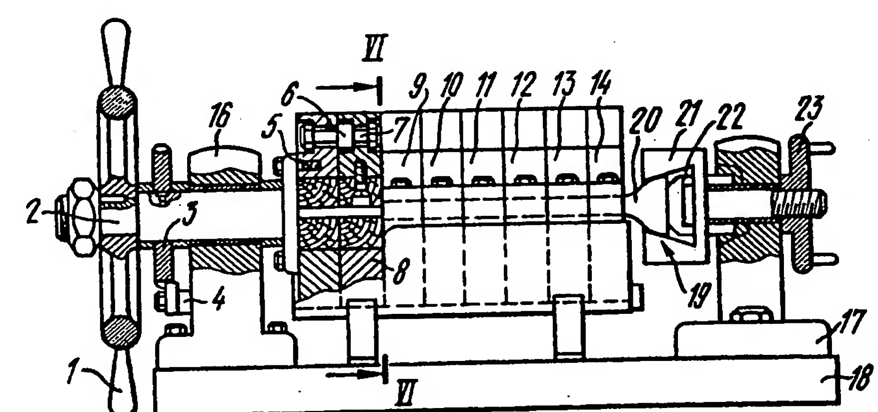

FIG.5

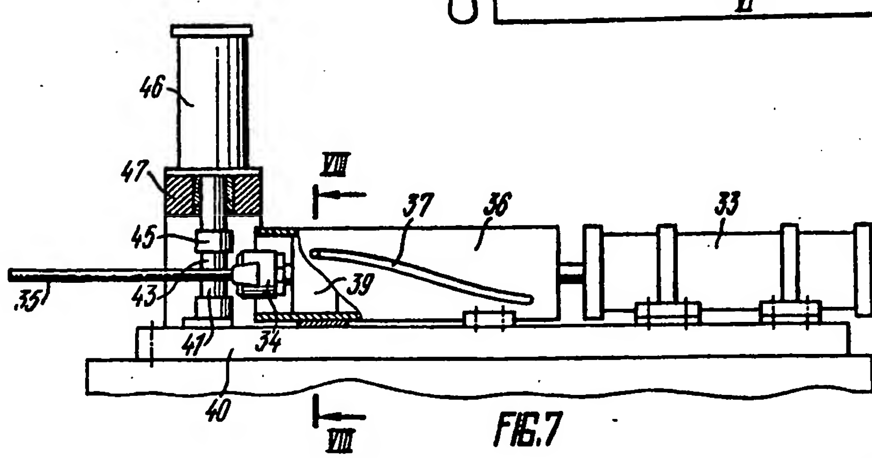

FIG.7

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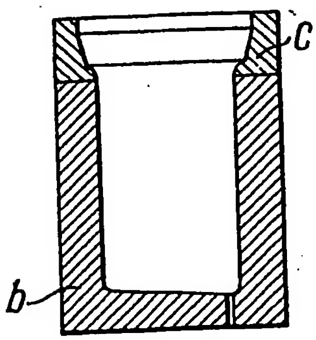


FIG.1

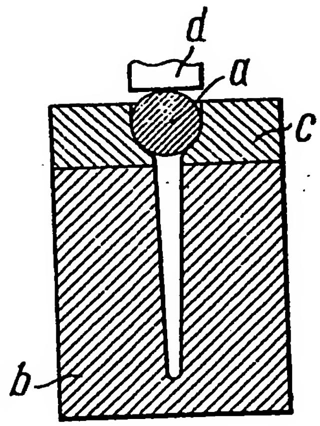
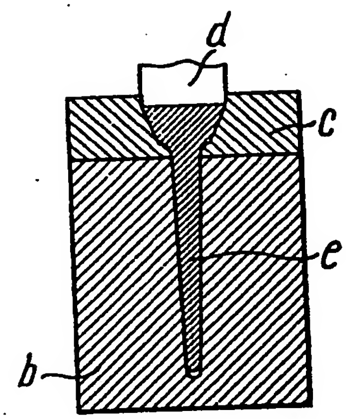


FIG.2



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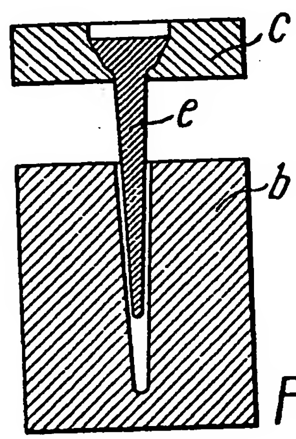

FIG.4

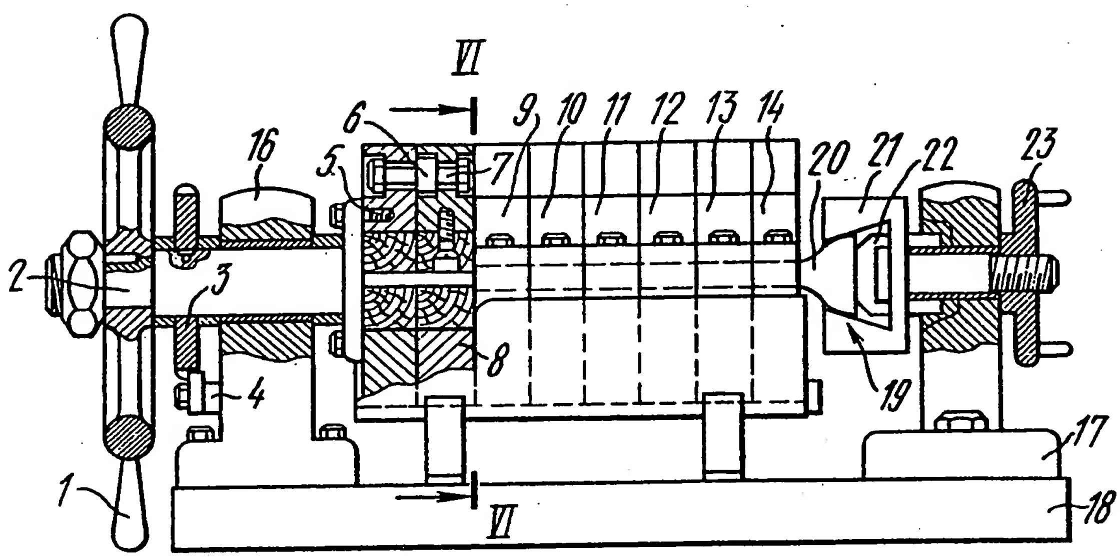
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FIG.5

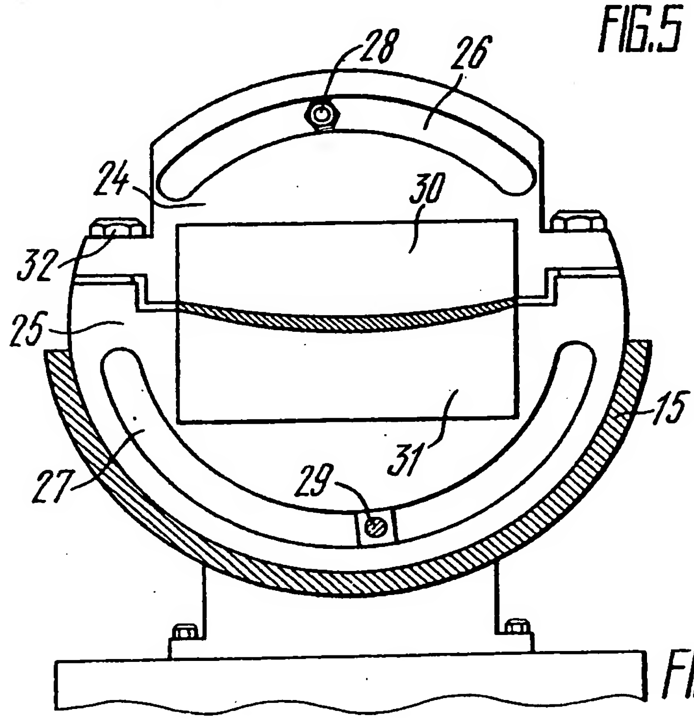
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FIG.6

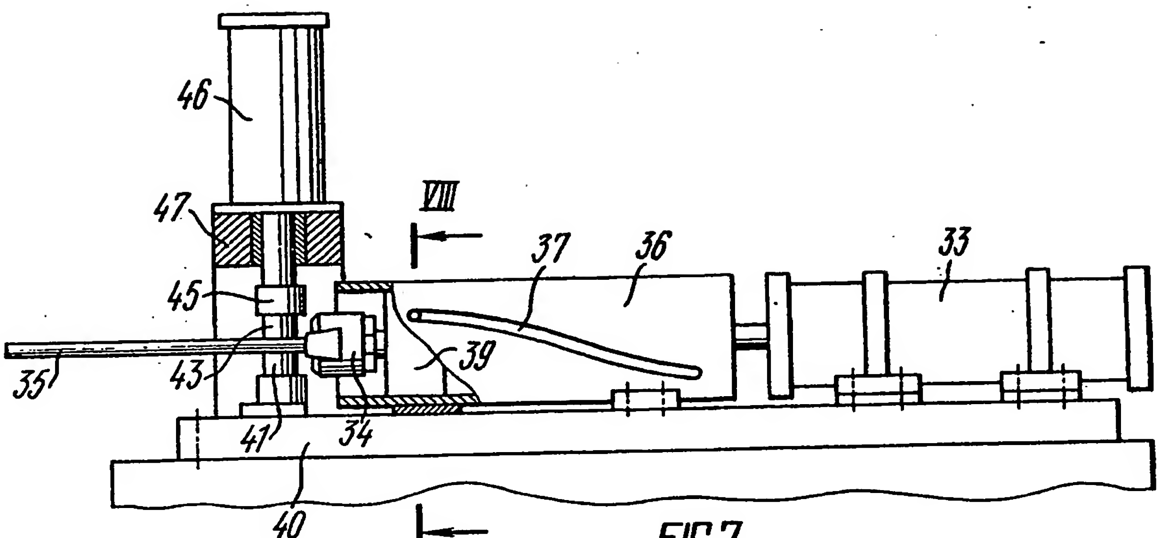

FIG.7

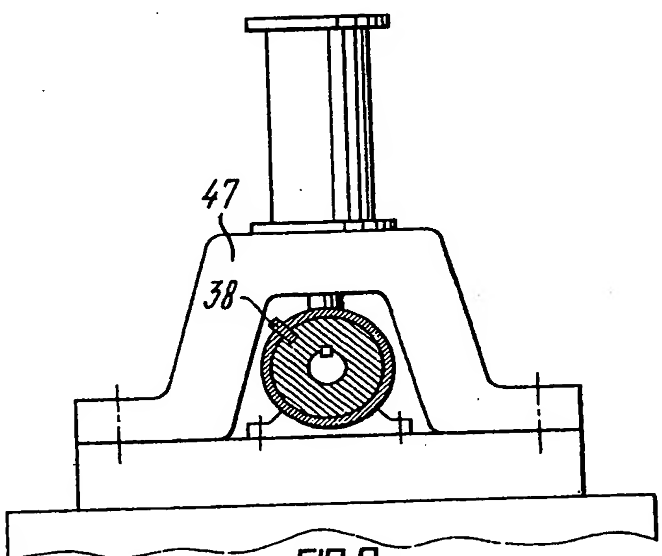

FIG.8

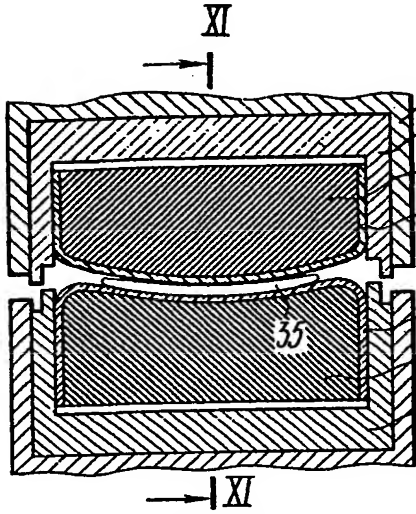

FIG.9

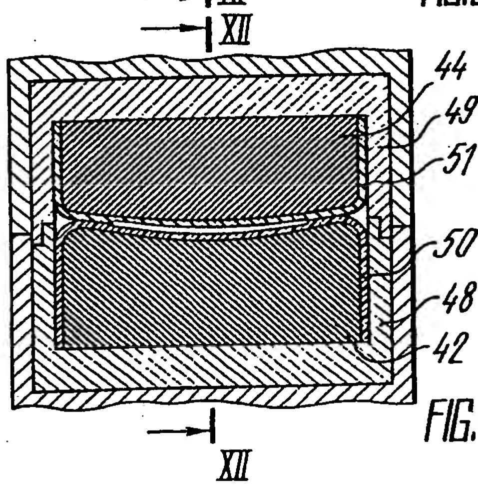

FIG.10

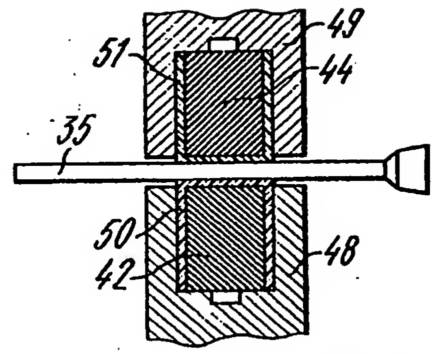

FIG.11

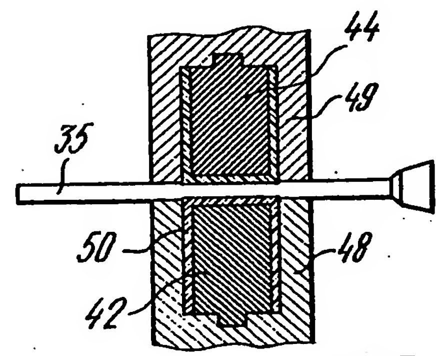

FIG.12

SPECIFICATION

Blade making m th d and blad twisting devices

The present invention relates to pressure working of metals and has particular reference to a method of making blades and devices for twisting the same.

This invention can be applied particularly with success in making blades for aircraft engine turbines and compressors and can also be used in making blades for steam and hydraulic turbines.

The invention provides a blade making method comprising:

(a) heating a blade blank;
(b) shaping said blade blank in a closed die in a superplastic state;
(c) machining said blade blank;
(d) twisting and heat treating said blade blank.

Shaping blade blanks in a superplastic state produces precision blanks in one operation. Furthermore, blade blanks shaped in a superplastic state compare fabourably with those produced by the methods of the prior art in that they possess enhanced plastic characteristics of the material and the entire set of their operational properties is about 15 to 20 percent higher. Also, the shaping force is decreased approximately three to five times, which enables using low-power presses.

The provision for twisting blades after machining them simplifies the machining process and saves labour since blades of plain configuration are dealt with.

Inasmuch as blades to be machined have no twist and are precision made, the machining process can be substantially simplified due to ease of positioning blades in machine tools, which also enables increasing the accuracy and stability of work.

The precision of blanks and the ease of their positioning in machine tools make it possible to omit preliminary machining operations such as removing fins, grinding blade surfaces and edges, etc., so that blades only need final polishing.

The method of the present invention provides for simplification of pressing by virtue of creating optimum conditions for die filling. This substantially saves labour consumption of the pressing process due to employment of a plain die outfit which can be produced by means of simplified machining, measuring and auxiliary equipment.

It is desirable that the shaping of blade blanks be carried out by extrusion into a blind cavity in a one-pi ce die. This method of shaping provides for producing precision-made blade blanks with good surface finish. Blade blanks produced by this method are practically devoid of edge fins due to which it is possible to dispense with machining allowance.

By producing blade blanks without fins, provision is made for substantially enhancing the quality of the product, inasmuch as the need for fin removal is excluded, which consequently, excludes the possibility of damaging blades and their edges in particular.

The proposed shaping of blade blanks by extrusion into a blind cavity of a one-piece die also provides for offsetting the effect of play, cocking and like faults of press ram movement on the shape and size of the blank. Th blade blanks produced by this method precisely reproduce the shape of the die cavity.

This method also provides for dispensing with uniform maching of the blade profile, whereby substantial savings (approximately 25 to 30 percent) are effected in material.

It is further desirable that, in order to extend blade life, blades be heat treated after they are given a twist.

Heat treating blades after twisting makes it possible to improve the conditions of working the blade material inasmuch as blade blanks, more specifically titanium alloy blade blanks, have a lower strength and a higher plasticity when they have not undergone a complete heat treatment. This feature also enables a smaller force to be used for twisting blades with consequent reduction of residual stress due to twisting.

Another important feature is that heat treating blade blanks after machining and twisting not only provides for substantially decreasing the residual stress set up on the blade surface by machining but also permits of practically completely eliminating the influence of the internal stress due to twisting on the operational characteristics of blades, more particularly on their fatigue strength.

In cases where large blades with a large angle of twist are made from low-plasticity materials, it is desirable that during the process of twisting they be rapidly heated to th starting point of intensive oxidation of the blade material.

Rapid heating of blades during the process of twisting provides for increasing material plasticity approximately two or three times, making it possible to effect twisting of blades of any configuration and size, and practically of any material used for blade production. Furthermore, this method provides for decrease in the required twisting force and, consequently, makes for enhancing the quality of twisting and the operational characteristics of the blades thereby produced.

The invention further provides a blade twisting device comprising a bed which mounts a tool adapted to grip a blade blank periodically over the length thereof, a feed mechanism f r m ving the blade blank l ngthwise in the process of twisting, which mechanism is c nstructed as a fixture with a driving means, a rotation mechanism for turning the blade

blank about the longitudinal axis thereof, which mechanism is construct d as a guide with a guiding gro ve and is connected with the feed mechanism by means of a rotatable disk which has a pin fitting into the guiding gr ove, said tool being composed of a top part and a bottom part, which top part has provision for reciprocating perpendicular to the axis of the blade blank, whereas the bottom part is stationary; elastic inserts being mounted on the tool portions facing the blade blank.

It is advantageous to use this device for giving a small-angle twist to thin blades. The device ensures high quality of the twisting job. The provision of elastic inserts on the tool liminates the possibility of causing scores, scratches, dents and other mechanical damage to the blade surface.

The invention yet further provides a blade twisting device comprising a tool constructed as a stack of rings each of which has a pin on one side and an abutment on the other, the abutment being arranged to engage with the pin on the adjacent ring; a power drive connected with the ring stack by means of a shaft; and a blank holding mechanism; the drive shaft mounting a ratchet wheel with a pawl; the rings being of divided construction and having changeable inserts shaped to correspond with the profile of the mating blade blank portion.

This device can be used for twisting blades of any size and configuration, including double-root blades and those having antivibration flanges. Besides, this device can be readily reset to another blade size by merely varying the number of the tool rings, changing their inserts and altering the twist angle by repositioning the abutments on the rings.

The invention will now be more particularly described by way of example with reference to the accompanying drawings, wherein:

Figures 1, 2 and 3 diagrammatically illustrate the process of shaping a blade blank in a blind cavity of a one-piece die,

Figure 4 diagrammatically illustrates removal of a blade from the die,

Figure 5 diagrammatically illustrates an embodiment of the blade twisting device according to the invention,

Figure 6 os a sectional view on the line VI–VI of Fig. 5,

Figure 7 diagrammatically illustrates another embodiment of the blade twisting device according to the invention,

Figure 8 is a sectional view of the line VIII–VIII of Fig. 7,

Figures 9 and 10 are longitudinal sectional views of the tool used in the device of Figs. 7 and 8, and

Figures 11 and 12 are sectional views on the lines XI–XI and XII–XII of Figs. 9 and 10.

The blade is made as follows:

The blank material in the form of rod is given a glass coating, heated and thereafter shaped in a closed die in a superplastic state. The blade so formed has no twist. After a number of intermediate operations (removing the glass coating and a defective skin), it proceeds to machining.

A blade blank formed in the rapid heating conditions of superplastic deformation possesses a high strength along with increased plasticity. This feature is most prominently shown by titanium alloys. ("The Use of the Effect of Superplasticity in Modern Metal Working", Moscow, NIIMash Publishers, 1977, page 17).

Said feature enables blades to be twisted after machining. Depending on the blade configuration, the angle of twist and the blank material, the devices for effecting the twisting operation can employ either elastic inserts and a guide or a stack of rings interconnected by abutments.

It will be noted that the blade section near the root need not be given a twist since its angularity with respect to the root is provided by shaping the blade blank.

In cases where large blades with a large angle of twist are made of materials whose plasticity is insufficient, they are rapidly heated during the twisting process to the starting point of intensive oxidation of the blade material, whereby plasticity of the material is increased.

In order to decrease blade residual stress due to twisting, heat treatment is carried out, as a rule, after the twisting operation.

An example of the blade making method is given below with reference to Figs. 1, 2 and 3.

A piece of titanium alloy rod, 18 mm in diameter by 32 mm long, was given a glass coating and heated to a temperature of 950 ± 5°C. Then the blank was put in a one-piece die comprising the lower die b and the upper die c and a punch d and equipped with an induction heater powered from a semiconductor frequency converter. The temperature in the shaping zone was maintained constant at 950 ± °C. The blank was extruded into the blind cavity in the one-piece die at a rate of 8–12 mm/min (Figs. 1, 2 and 3).

Thereafter the blade blank was removed from the die (Fig. 4). The blade thereby shaped had no twist and was provided with a machining allowance of 0.1 mm on the blade working part and 0.2 mm on the root part. Then the remaining glass coating was removed from the blade surface by sandblasting.

A skin of 0.03–0.04 mm caused by the action of the surrounding medium on the blade surface was removed by pickling in a solution of nitric and hydrofluoric acids.

The blade was machined as follows:

First, with the blade gripped by the working part, the root was machined. Then, with the

root gripped, the working part of the blade was polished. Upon completion of the machining and after checking the blade profile, the blade proceeded to the twisting operation.

The twisting operation was performed by the use of a device (Figs. 5 and 6) comprising a driving means 1 mounted on shaft 2 which carried a ratchet wheel 3 and a one-piece driving ring 5. The ratchet wheel 3 is engaged with a pawl 4. The driving wheel 5 engages through a changeable abutment 6 and a pin 7 with a divided ring 8 and therethrough with divided rings 9, 10, 11, 12, 13 and 14. All the rings 5, 8, 9, 10, 11, 12, 13, and 14 are installed in a case 15 mounted on a base 18. Also mounted on the base 18 are supports 16 and 17. A blade holding mechanism 19 is designed to hold a blade 20. It is mounted on the support 17 and comprises a movable fixture 21, an abutment 22, and a handwheel-operated screw 23. Each of the rings 8, 9, 10, 11, 12, 13, and 14 is composed of an upper part 24 and a lower part 25 which have grooves 26 and 27 accommodating abutments 28 and 29. The upper parts 24 and the lower parts 25 of the rings are provided with changeable shaped inserts 30 and 31 and are held together by bolts 32.

Before the twisting operation the blade 20, which is already machined, is installed in the blade holding mechanism 19 by fitting it in the fixture 21, which is screwed on the screw 23, and gripping blade root. The working part of the blade is placed on the inserts 31 provided in the lower parts 25 of the rings 5, 8, 9, 10, 11, 12, 13, and 14. Then the ring upper parts 24 are secured to the lower parts 25 by means of the bolts 32, whereby the blade 20 is tightly clamped between the inserts 30 and 31 in the entire stack of the rings 5, 8, 9, 10, 11, 12, 13 and 14. The ring 5 has inserts 30 and 31 shaped to correspond with the profile of the tip section of the blade 20.

When the driving means 1 is rotated, power is transmitted to the driving wheel 5, and therefrom, via the abutment 6 and the pin 7, to the ring 8, thence, likewise via an abutment and a pin, to the next ring 9, and thence to the next rings 10, 11, 12, 13, and 14. The abutments 6 and the mating pins 7 are positioned relative to each other so that each ring turns through the required angle, the elastic deformation of the blade 20 being taken into consideration, in order to effect twisting of the mating blade portion. The driving ring 5 turns through a maximum angle, whereas the last ring 14 turns through a minimum angle. Accordingly, the tip portion of the blade 20 acquires a maximum twist, whereas the blade section at the root acquires a minimum twist.

Th ratchet wheel 3 rotates togeth r with the driving means 1 and, by engagem nt with the pawl 4, locks the driving means 1 in position so that, if necessary, the blade is kept und r the appropriate twisting load for any time.

After the blade 20 is twisted to the design angles, it is held under the load for 20 to 30 seconds, whereupon the bolts 32 and the bolts securing the support 17 are undone and the blade 20 together with the support 17 is removed from the device. Now the fixture 21 is released by operating the screw 23 and the blade is freed.

To deal with a blade of another shape, or in case of wear on the profiled surface of the ring parts 24 and 25, the shaped inserts 30 and 31 in the entire ring stack are to be replaced. In most cases the inserts 30 and 31 are made of hardwood to provide against damaging blades.

After the blade is twisted, it is heat treated at a temperature of 530°C for 6 hours.

For large blades with a large angle of twist, recourse is had to rapid heating of the blade working part to the starting point of intensive oxidation of the blade material in order to increase plasticity of the material and thereby facilitate blade twisting.

To give a small angle of twist to thin blades by application of comparatively small forces, use is made of the embodiment of the device illustrated in Figs. 7 and 8 which comprises a hydraulic power drive 33 and a holding mechanism 34 for holding a blade 35. The path of travel of the blade holding mechanism 34 is determined by a cylindrical guide 36 having a guiding groove 37 which receives a pin 38 secured to a rotatable disk 39 of the power drive 33. A bottom plate 40 mounts a bottom part 41 of a tool. The bottom part 41 is provided with an elastic insert 42 made, for example, of rubber (Fig. 9).

A top part 43 of the tool is also provided with an elastic insert 44 which is secured by means of a member 45 to the piston rod of a hydraulic cylinder 46 mounted on a top plate 47 (Figs. 7 and 9). The inserts 42 and 44 of the tool are made of elastic rubber chosen to suit the conditions and forces of the job. Th device also includes metal housings 48 and 49 with elastic caprone strips 50 and 51 (Figs. 9 and 11).

The device operates as follows:

The blade root is gripped in the holding mechanism 34 and the back of the blade 35 near the root is placed on the bottom part 41 of the tool. The top part 43 of the tool is moved down by the hydraulic cylnder 46 so that the elastic inserts 42 and 44 tightly grip the blade 35 in the tool with a force appropriate to th twisting force to be applied (Figs. 10 and 12). Then, und r the action of the power driv 33, the blade 35 is moved axially at a constant speed of 120–140 mm min in the path determined by the guide 36, between the bottom part 41 and the top part 43

of the tool, acquiring a twist. As the thickness of the blade varies with the movement of the blade 35, the top part 43 of the tool moves down so as to follow the blade shape and create an appropriate force in the twisting zone.

In order to decrease friction between the tool and the blade, impulse pressure is created in the twisting zone by varying the load imposed on the top part 43 of the tool. In so doing, the force transmitted to the blade 35 varies from minimum to maximum at a frequency of 40 to 60 cycles per minute. Variation in the force exerted on the blade 35 is effected at the required frequency by means of the hydraulic cylinder 46 and conventional hydraulic circuits operating on the principle of hydraulic fluid throttling.

After the blade twisting operation is accomplished, the top part 43 of the tool is lifted and the blade 35 is returned into the initial position by the action of the power drive 33 and thereafter is removed from the device.

The tool employed in the device operates as follows (refer to Figs. 10 and 12):

When the top part 43 is moved toward the bottom part 41, the caprone strips 50 and 51 come into contact with the blade 35, change their shape in company with the inserts 42 and 44, and assume an equidistant position in relation to the blade profile. This continues until the elastic inserts 42 and 44 fill up the metal housings 48 and 49, at which instant the inserts 42 and 44 grip the blade tightly and begin to work solidly in a confined space.

Further increase in pressure on the top part 43 of the tool does not cause any substantial change in the position of the blade 35, wh reas unit pressure thereon increases. After th top part 43 of the tool is relieved of the load, the inserts 42 and 44 take the initial position, releasing the blade 35 so that the latter can be moved by application of a small force. Repeated loading of the top part 43 of the tool again causes the inserts 42 and 44 to assume an equidistant position in relation to the blade profile and to work solidly.

As a blade 35 moves axially through the tool, its thickness decreases from the root towards the tip and the blade shape varies. During the twisting operation decrease in the blade thickness entails decrease in the pressure exerted by the top part 43 of the tool on the blade 35, which permits the elastic inserts 42 and 44 to change their shape and assume an equidistant position in relation to the profile of all the blade sections being twisted.

Inasmuch as the power cylinder 46 provides a predetermined pressure on the blade 35 during the twisting process, the top part 43 of the tool attached thereto reacts t the pressure change by moving down.

Thus, provision of elastic inserts 42 and 44 and of movable top part 43 of the tool nables following the shape and thickn ss of the blade 35 during the twisting process so as to maintain the required twisting force.

CLAIMS

1. A blade making method comprising:
(a) heating a blade blank;
(b) shaping said blade blank in a closed die in a super-plastic state;
(c) machining said blade blank;
(d) twisting and heat treating said blade blank.

2. A method as in Claim 1, wherein the blade blank is shaped by extrusion into a blind cavity in a one-piece die.

3. A method as in Claim 1, wherein the blade is heat treated after twisting.

4. A method as in Claim 1, wherein during the twisting process the blade is rapidly heated to a starting point of intensive oxidation of the blade material.

5. A blade twisting device comprising a bed which mounts a tool adapted to grip a blade blank periodically over the length thereof; a feed mechanism for moving the blade blank lengthwise in the process of twisting, which mechanism is constructed as a fixture with a driving means; a rotation mechanism for turning the blade blank about the longitudinal axis thereof, which mechanism is constructed as a guide with a guiding groove and is connected with the feed mechanism by means of a rotatable disk which has a pin fitting into the guiding groove; said tool being composed of a top part and a bottom part, which top has provision for reciprocating perpendicular to the axis of said blade, whereas the bottom part is stationary; elastic inserts being mounted on the tool portions facing the blade blank.

6. A blade twising device comprising a tool constructed as a stack of rings each of which has a pin on one side and an abutment on the other, the abutment being arranged to engage with the pin on the adjacent ring; a power drive connected with the ring stack by means of a shaft; and a blank holding mechanism; the drive shaft mounting a ratchet wheel with a pawl; the rings being of divided construction and having changeable insertes shaped to correspond with the profile of the mating blade blank portion.

7. A blade making method substantially as described herein with reference to the accompanying drawings.

8. A blade twisting device substantially as described herein with reference to and as shown in Figs. 5 and 6, or Figs. 7–12, of the accompanying drawings.

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